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*BITTER ROT OF APPLES.

By Thomas J. Burrill, Chief in Botany, and Joseph C. Blair, Chief in Horticulture.

There is no other disease which is so enormously destructive to the apple fruit as is the one commonly called "bitter rot." Its ravages at times constitute a veritable pestilence, so that apparently within a few days the richest promise of the finest crop, perhaps almost mature, results in nothing but a mass of corruption and calamitous disappointment. It occurs over a very wide area of the American continent from Maine to Texas, and perhaps everywhere that apples are grown; but its effects seem to be serious only in southerly regions. In Illinois, though the disease has been found much further north, it has not caused alarming destruction far above the 39th parallel of north latitude, or much north of Effingham and Jerseyville. It is altogether possible, however, that pestilential outbreaks of the disease may sometimes occur further northward, at least there is nothing known to prevent the spread of the pest throughout the state.

The disease so far as its effects are concerned has been long known and its ravages in Illinois a quarter of a century ago were, in proportion

*On July 14th Circular No. 58 was issued from this Experiment Station, entitled "Prevention of Bitter Rot." This circular gave what information there was at hand at that time, and the fruit growers were advised to search for and remove as speedily as possible all diseased apples and cankered limbs.

to the area of orchards existing, as great and as direful as at any subsequent time. The worst outbreak in quite recent years occurred in 1900, when it was estimated that $1,500,000.00 worth of fruit was destroyed upon the trees in four counties of our state, where investigations were more especially made. Presumably the losses were as great in other apple growing regions subject to the disease.

Infected apples have already been found this year (July 24, 1902) in nine counties, all except Champaign lying south of the line mentioned, but extending entirely across the state. Commonly the disease works its baneful destruction later in the season, during August and September, though it may be inferred that its earlier appearance has heretofore escaped observation. Attention has been especially given to it this year. The first record of its existence on young apples was made June 28th, but the specimens showed that the infection must have been at least two weeks earlier, and it has been otherwise sufficiently proved that in numerous instances the attack occurs as soon as the middle of June.

The rapidity of development depends upon climatic conditions. It is essentially a hot weather disease, and moisture is necessary for the distribution and germination of the spores. It is true that the infection of the fruit sometimes becomes apparent and the progress of the disease is abundantly evident when the atmosphere is very dry; but this only happens after the fungus has gained entrance to the apples, which must have occurred during a previous period of rainy weather. Rain and high temperature are necessary to start an epidemic. These, of course, are only favorable conditions for the development of the fungus which is, itself, the direct agent of destruction. Fortunately the latter is not very resistant to unfavorable conditions and may die out entirely during one year where it has been previously abundant. This, with its power of enormous multiplication under circumstances well suited to its growth, sufficiently accounts for the marked irregularity in the time and virulence of its attack.

The Disease upon the Fruit.—Anyone who cares to do so may readily identify the disease as it occurs on growing apples. The points of infection vary from one to a countless number, commonly, however, from one to not more than a half dozen. At first these are minute, brown specks ; later they enlarge so as to make each a conspicuous, dark-colored, circular spot, which, while preserving its circular form and maintaining a sharply defined border, gradually extends to become perhaps an inch or more in diameter. The affected area does not become soft, but is soon depressed or somewhat sunken while the skin assumes a leatherly appearance. The outer portion of the spot remains smooth and polished while the central area looses its lustre and becomes

roughened by the formation of a multitude of minute pustules arranged in irregular, concentric circles. When the atmosphere is not too dry each of these little pustule opens and there exudes in microscopic masses, or columns, a waxy substance, which is at first pale pink in color, then pale dull red, or at length grayish when long exposed to the sun. The spot ultimately becomes shriveled in appearance, tough in texture, and very dark—approaching black—in color. When there are to begin with several spots they run together but commonly preserve some indication of the original centers of each in the general area of infection.

The diseased apple finally becomes dark brown throughout, and shriveled into a dry, hard, and much wrinkled mass called a "mummy." This may remain firmly attached to its twig on the tree for a year or more, but commonly falls to the ground before the drying process is entirely completed.

The exuding material from the little pustules is at first of the consistence of thick mucilage, and in this condition that from neighboring pustules may run together in masses of still small, but variable size. In dry weather the substance becomes harder and forms little waxy crusts adherent to the surface of the fruit. At no time does this become dusty or capable of being carried by the wind. An appeal to the microscope shows that the material is composed of myriads of oblong, thin-walled spores, each of which is capable of starting by germination and penetration of the skin of an apple an infected spot like that from which it came. The substance which renders them adhesive and keeps the mass when dry together is very soluble in water. When placed in a drop of this liquid the spores readily separate from each other and are then easily distributed in any degree of dilution with the fluid. This characteristic must be borne in mind in the discussion to follow and in connection with the methods recommended for the prevention of the disease. It is worthy of note that while the spores are imbedded in the waxy masses and kept dry they retain their vitality during many weeks and even months, but when once dissolved in water subsequent drying kills them. If kept moist they germinate and then quickly perish if they do not find the proper nutriment. It is impossible, therefore, that these spores should long retain their vitality when exposed to the weather, and altogether unlikely that they ever live over winter out of doors. After one infected apple begins to produce spores the disease may be spread on the tree by the splashing of rain drops, or the adhesive spores may be readily carried by insects. It is now well understood, however, that the progress of infection from tree to tree in an orchard is usually slow, and still slower from orchard to orchard. Sporadic cases are always liable to occur, of which the origin cannot be traced; but the idea that the disease starts suddenly throughout a large

area where it had no existence previously is not tenable, and can only have been held by anyone through faulty observations.

How Does the Fungus Pass the Winter?—Until recently nothing has been known as to where and how the parasite passes the winter and how the first infection of summer occurs. In Bulletin 69 of the Agricultural Experiment Station of the University of Illinois, issued in February, 1902, George P. Clinton, Assistant Botanist, gave the results of his studies during July, August, and September of the preceding year. He showed that the fungus produced a second form of fruit or spores in artificial cultures and that these spores developed, under certain conditions, on old diseased apples (mummies). From this he inferred, without chance however to verify the supposition, that the fungus lived through the winter on such mummified apples and that the newly found second kind of spores produced the primary infection of the succeeding year. That this may sometimes be true is quite possible; it is even probable, but further observations have not so far established the fact.

During the autumn of 1901 Mr. H. Hasselbring of the Illinois Agricultural Experiment Station took up the work as it was left by Mr. Clinton. Many diseased, shrivelled apples (mummies) were collected and kept under different conditions for studies during the winter and spring. Hasselbring never found the second spore-forms described by Clinton on such apples kept out of doors, but he has found that the fungus ordinarily retains its vitality in a dormant state in the winter and in May, or later, under proper conditions begins to produce again the same kind of spores, borne on fertile threads of the fungus, in the same manner as it did the preceding summer. Spores so secured from old mummies were inoculated into green apples on June 8th of the present year and produced typical bitter rot spots. This was repeated with spores from bitter rot mummies collected in different parts of the state and was found to be an easy procedure. The spring infection may therefore start from these old apples, and recent observations in the field have given indisputable evidence that it does sometimes so occur.

It is a fact, however, that the bitter rot mummies usually fall from the tree, and the question has been a puzzling one how the spores, not capable of being carried by the wind, can rise from the ground. There is indeed no proof that they do this. The supposition that they are carried by insects is purely speculative. In multitudes of cases the disease starts where no mummy remains on the tree. It has been long observed, however, that the early infection on a tree took the form of a triangle or cone as shown by the spots on the apples. At the apex of this area one or two green apples commonly show rot spots larger

and older than those below, and the inference was a most natural one that these fruits gained infection from spores produced on old mummies, and that other apples beneath them received spores carried in rain water from those first infected. Still the explanation was wanting as to how these fruit spores were carried from the old mummies on the ground to the upper parts of the tree, and Hasselbring found this year that the most careful collection and destruction of these old diseased fruits failed to prevent outbreaks of the disease.

All this was held in mind when the undersigned started on a trip of inspection and study through the main apple-producing regions of the state. Anything whatever touching the origin and development of the disease was considered highly important and received the utmost attention. On July 11th Captain R. A. Simpson† of Vincennes, Indiana, expressed, in answer to a question, the opinion that the disease on the earliest affected apples upon a given tree was traceable in each case to an old rough wound on one of the branches, and going with us to trees having infected fruit he pointed out in several cases that just above the area of infection there was usually to be found such a wound-spot on a limb. This was a new observation‡ and Simpson's discovery was quickly taken up for verification. Further search in various orchards gave continuously increasing support to the probable correctness of this supposition, and microscopic examinations made July 12th and 13th in the Station's laboratory at Salem, Illinois, contributed greatly towards a confirmation of the connection between cankered places on the limbs and the disease upon the fruit; for it was found that many spores, identical with those from the minute pustules of the rot-spots on apples were exuding in the familiar, pinkish, waxy masses in places from the dead bark. Further examination showed that these bark-borne spores originate from the free ends of closely clustered threads of the fungus, just as those from the mummied apples are produced. This is clearly shown in figures 9 and 10 drawn from nature by Mr. Hasselbring. Inoculations made July 13th, in green apples of spores taken from cankers on limbs produced in four days typical bitter rot.

†Mr. Simpson had direct supervision of spraying experiments for bitter rot last year at Parkersburg and Odin conducted jointly by the Illinois Experiment Station and the Division of Vegetable Physiology and Pathology of the United States Department of Agriculture, and this year has charge of similar experiments at the former place for the above named Division under the direction of Dr. Herman Von Schrenk.

‡On July 14th Mr. W. P. Storment of Kell, Illinois, showed one of us a cankered limb which he had cut from a tree and from which he had tried the previous week to infect apples by applying to their surfaces water with which the canker had been washed. His observations had led him to suspect that the early infection of the fruit came from the limb canker.

It therefore became evident that the disease on apples could come from these spots on the branches, and everything now goes to show that except in the few cases that the rot mummies hang over winter on the trees, the first or early infection comes solely from these limb-cankers. This is of the greatest importance in connection with the prevention of an outbreak of the disease. The identification and removal of the affected branches is not difficult and if done in time must be effectual in preventing the disease on the fruit.

Bitter Rot Canker.—The term canker is a convenient one for the rough wounds made by the fungus on limbs, but several other kinds of corroding or spreading, diseased spots on the bark of trees are loosely designated by this name, making it necessary to speak of this as the bitter rot canker. It is altogether different in origin and appearance from the "Illinois apple tree canker" described in Bulletin 70 of this Station, which for the most part attacks the trunk and larger branches. The bitter rot canker is found more often than elsewhere on limbs from a half-inch to one inch in diameter, though sometimes on mere twigs or fruit spurs, and sometimes on limbs twice or more the maximum size given. It starts, at least in many cases, from a mechanical bruise or other injury to the bark. Sometimes the canker is found as a ragged border to the rough wound made by breaking a limb half off. No doubt it often starts in bruises made by the ladder at the time of gathering fruit, and it appears in some cases to begin in a very small twig and then run down to and spread in the bark of a larger limb. The wood is not destroyed, though it dies under the affected bark. Growth takes place around the diseased area as it does about any wound, and there is formed in an irregular, encircling rim of healing tissue about a dead and depressed, or sunken, usually elongated, black patch, covered with dead bark. On very small twigs the rim of growth may be slight or none, but the spore-producing places are always dead and dry except as wet with rain. At this season of the year (July) the fungus does not seem to exist in the living bark. It is never found on or in the leaves. The canker in the limbs is commonly at least only one year old; the fungus does not persist perennially in the bark. The appearance of the canker can best be learned from the illustrations, figures 4 to 8.

Old trees long infested with the fungus may have many cankered spots on the limbs, and certain varieties—the Huntsman for instance—are liable to have numerous diseased branches; but it now seems to be commonly true that the cankers are few in number, at least upon the kinds of trees ordinarily planted in Illinois and not over 15 years of age. Only a tree here and there in orchards in which the disease was prevalent one and two years ago is now found to have any indi-

cations whatever of the malady. The spots on the apples can now be easily seen by looking closely for them, but the cankers are not easy to discover in the leafy tree without some guide to their location. As before said the early infected apples appear beneath the cankered spots on the limbs and spread through the branches in a cone-shoped area; if, therefore, the spotted apples can be seen, the canker may be sought at the apex of the cone, and experience proves that it can in most cases be easily found in this way. Figure 1.

PREVENTIVE MEASURES.—From the results so far obtained by this Station, and from the recent experience of several practical orchardists the following preventive measures are recommended:

The orchard should be examined systematically, following the rows tree by tree and making the sharpest possible search for the rot spots on the apples. It is best that the examination be made from an elevated position so as to look down upon the fruit as much as is possible, the first infection taking place on the upper surface of the apple as a rule. Drive down between the rows with a spraying outfit, having two men stand upon the operator's platform, a man looking at each side. Drive slowly, and if an apple looks suspicious, drive closer so that a careful examination can be made. Figure 11 shows three men at work making an examination in the Schwartz Brothers' orchard at Salem. Seventy acres of orchard were critically examined in this way in less than three days. After the infected trees have been located trace all of the diseased apples until the cankered limb, which is the source of infection, has been found. These infected limbs and fruit should be removed from the orchard and burned. Figure 1 shows a cankered limb at X just below the knife, which is sticking in the limb. Looking at the fruit (in the angle made by the lines) from this source of infection one can see the spotted apples. These spots, however, have been somewhat darkened in the photograph so as to bring out more clearly their condition. The work of removing fruit and limbs should be done cautiously, so as not to spread infection. The operator who goes into the tree top should be careful not in any way to cause the rupture of the bark.

In orchards where bitter rot has not yet made its appearance, but where there seems to be some likelihood from past experience of its making its appearance, it would be well to be on the safe side and give a thorough application of Bordeaux mixture.

During the present year the University of Illinois has been carrying on experiments with bitter rot in orchards at Tonti, Flora and Tamaroa. This work, together with results obtained from the experiments conducted last year, and reported in Circular No. 43 of the Experiment Station, prove conclusively that spraying with Bordeaux mix-

ture before bitter rot makes its appearance upon the fruit, is a means of holding the disease almost absolutely in check.

Only a brief statement of these results can be made at the present time. The details will be left for a separate publication to be issued when the season's work is completed.

In an orchard at Tonti, where part of our experiments are in progress, it was found, on July 8th, that bitter rot had developed on unsprayed trees, while those which had been sprayed every ten days up to June 17th had no infected fruit. In this same orchard Ben Davis trees which had been sprayed showed no evidence of bitter rot, while an occasional infected apple could be found on those trees receiving no spray. From two unsprayed Huntsman trees there were taken on July 9th, 647 infected apples, while from a tree which had received Bordeaux mixture every ten days there were but 6 infected apples ; or 54 rotten apples per tree where there was no spraying as against one where the trees were treated. On July 12th it was still found that bitter rot had not further developed on the sprayed trees, either Ben Davis or Huntsman, while on the unsprayed the disease was spreading rapidly. On July 19th but three infected apples were taken from the sprayed areas, while on the unsprayed areas the disease had become well established on a greater portion of the fruit.

The exact percentage of fruit saved by spraying will be clearly determined when the records are compiled at the end of the season's work—records which will have been secured from three commercial orchards. It seems certain, however, that spraying which is started now in orchards reasonably free from the disease will do much to stop the progress of bitter rot.

A limb taken from an infected tree, and yet which was well sprayed, is shown in figure 12. It will be noticed that this fruit, which is well covered with the spraying mixture, is entirely free from the disease.

The fruit grower himself must be the judge as to whether or not the condition existing in his orchard warrants spraying or the removal of the diseased limbs and fruit. In most orchards it is quite probable that both methods should be employed.

In order entirely to free an orchard from bitter rot, it is more than likely that winter pruning and spraying will be the proper procedure. At that season of the year the diseased limbs would be more easily detected, and at that season, also, a strong solution of pure copper sulphate can be applied to the twigs and branches. It is probable that in this way the disease can be stamped out, at least in most localities, and at comparatively very little cost.

FIGURE 1.
TRIANGULAR DISTRIBUTION OF ROT IN TREES, AND SOURCE OF INFECTION AT X.

FIGURE 2.
THE CANKERED LIMB SHOWN IN FIG. 1 AND ALSO SOME AFFECTED APPLES FROM IT. FRUIT PICKED SEVERAL FEET BELOW THE SOURCE OF INFECTION.

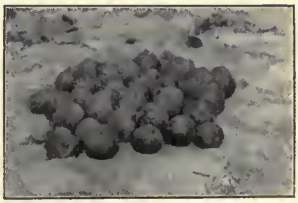


FIGURE 3.
DISEASED APPLES TAKEN FROM INFECTED AREA SHOWN IN FIG. 1.

FIGURE 4.
A CANKERED LIMB WITH DISEASED APPLES BENEATH IT.

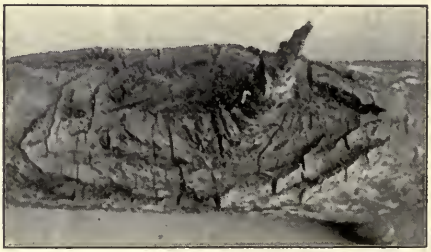


FIGURE 5.
A BITTER ROT CANKER.

FIGURE 6.
TYPES OF BITTER ROT CANKER.

FIGURE 7.
DISEASED APPLES AND CANKERED LIMBS.

FIGURE 8. BITTER ROT CANKER.

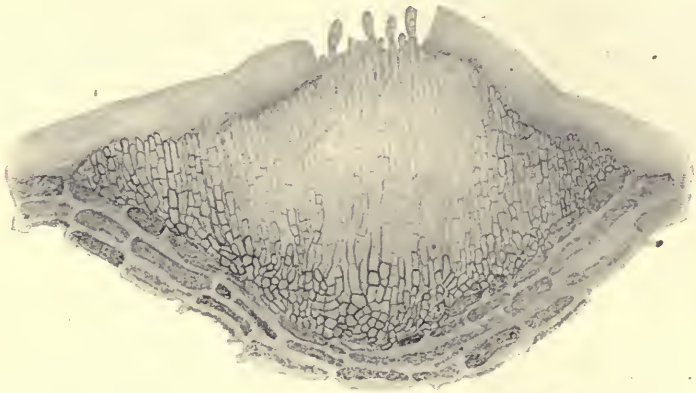


FIGURE 9. PUSTULE OF BITTER ROT FUNGUS ON MUMMIFIED APPLE. SPORES IN OPENING ABOVE. (HASSELBRING.)

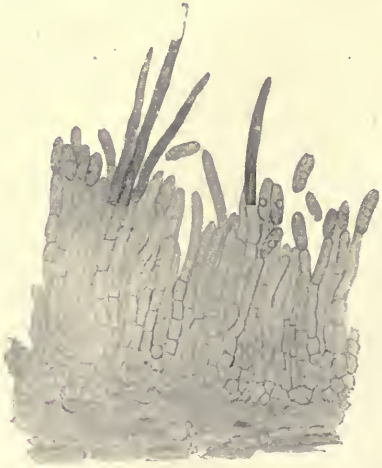
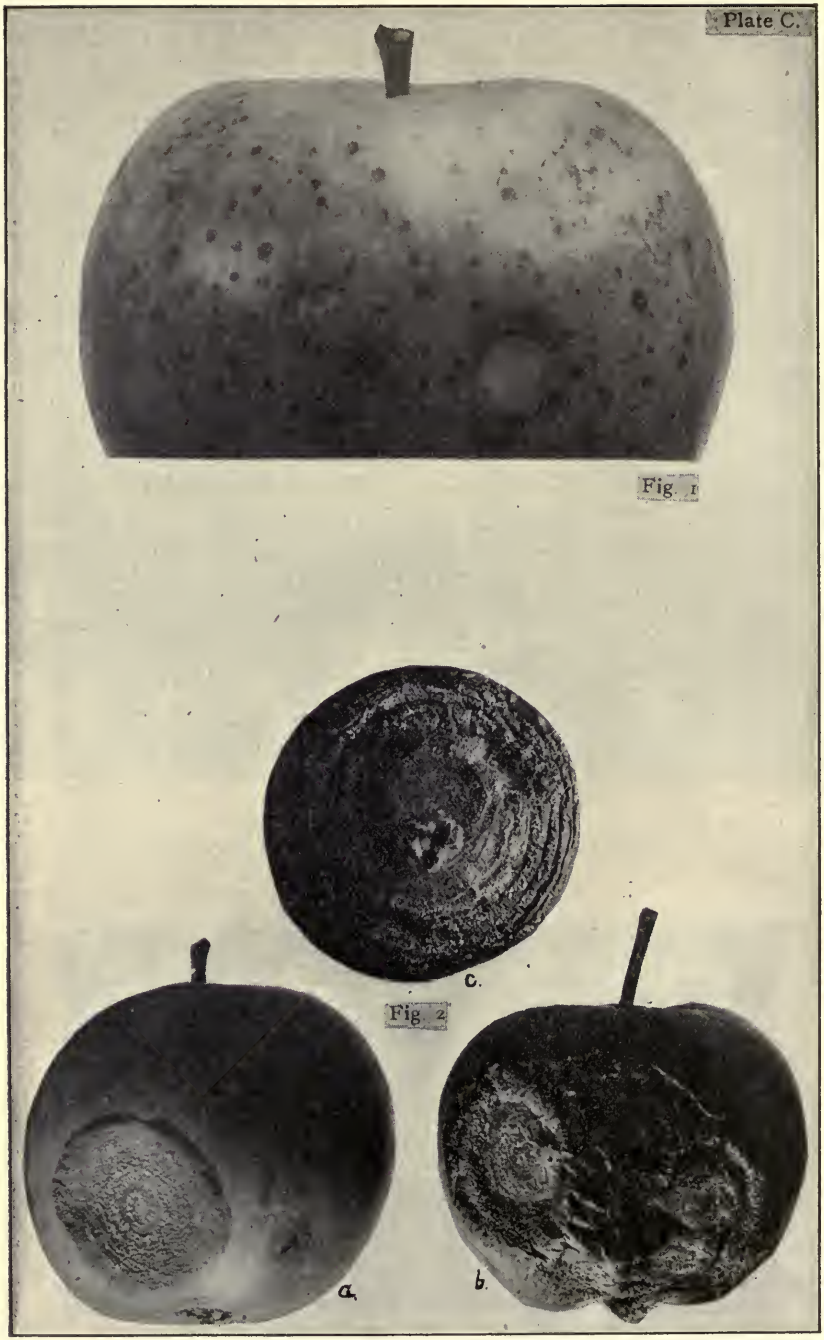


FIGURE 10.
PART OF A PUSTULE FROM BITTER ROT CANKER ON LIMB. (HASSELBRING.)

FIGURE 11.
LOCATING TREES INFECTED WITH BITTER ROT.

FIGURE 12.
SPRAYED APPLES FREE FROM BITTER ROT.



DIFFERENT STAGES OF BITTER ROT. (CLINTON.)

SUMMARY.

Losses Caused by Bitter Rot.

Bitter rot is a disastrously destructive disease upon the apple fruit. It has prevailed at times over very large areas of the territory of the United States, but is especially liable to occur south of the 39th parallel of north latitude. In Illinois in 1900 the loss in four counties was estimated to be $1,500,000.00 and as great proportionally to the acres in orchards elsewhere.

Appearance of Diseased Apples.

The disease on the fruit can be easily identified. Plate C, page 364. It begins in one to many brown specks anywhere upon the unbroken skin of the apple and each point of infection enlarges so as to become a very distinct, dark-colored, circular and somewhat sunken spot, beneath which the tissues are dry (never soft and watery) and tough. Great numbers of pustules so small as to be scarcely visible to the unaided eye, arranged in close concentric circles cover all but the outer border of the discolored spot and give to the surface a roughened appearance. In very dry weather these pustules are merely minute, raised, dark-colored points, but when the air is sufficiently moist each conically shaped point opens by breaking through the skin of the fruit and discharges a little pinkish mass of a mucilaginous or waxy substance well seen under a lens. This material may at length form a reddish, minutely roughened crust. Each spot may remain distinct or several on one apple may run together so as to form an irregularly shaped, depressed patch. The whole fruit at length becomes shriveled into an angular, hard body called a "mummy." It does not further decay.

The Dissemination of the Disease.

The pinkish or reddish material from the spots in the fruit is composed of myriads of spores. These cannot be distributed by the wind because they are held together and to the fruit by an adhesive substance, which, however, is very soluble in water. The spores are carried in splashes of rain water or may be distributed by insects. The fungus lives over winter in the old, dried fruits (mummies) and in wound-like infected spots, called bitter rot cankers, on the limbs of the tree. During the month of May or later a fresh crop of spores may be produced from the mummies and from the limb cankers. The former more often fall from the tree. The first infection of the season apparently comes from the cankers and can be traced on the young apples

spreading below these in cone-shaped figures in the trees, where the spores have been carried by rain.

The disease goes slowly from tree to tree in an orchard, probably through the agency of insects.

Prevention of the Disease.

At this season of the year (July) and later where the disease has not become widely spread, search should be systematically made in the orchard for infected trees as determined by the spots on the apples. This can best be done from an elevated position like the platform of a spraying outfit. If diseased apples are found the infecting canker (or mummy) should be looked for just above the uppermost of the spotted fruit. The canker and infected fruit should be removed, taking care not to distribute the infection in the process. This is of the utmost importance if the contagion is to be stopped.

In the winter time the mummies and cankers can be removed or the fungus probably destroyed by spraying the trees with copper sulphate.

The disease can be kept in check during the summer by repeated applications of Bordeaux mixture.